(54) SEMICONDUCTOR MANUFACTURING APPARATUS

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Specification

Title of the Invention

Semiconductor Manufacturing Apparatus

Scope of Patent Claims

A semiconductor manufacturing apparatus; characterized in that it is configured to perform, via a liquid, detection of a pattern on a substrate on which a photosensitive material has been coated or exposure and formation of a pattern.

Detailed Explanation of the Invention

The present invention relates to a manufacturing apparatus for highly integrated semiconductor devices, etc. that use fine patterns.

Among semiconductor manufacturing processes, the lithography process, which forms a fine pattern on a substrate, is the most important, and photographic technology that uses light is the main current for this process at present.

In demand in this lithography process is, in addition to higher integration and higher density of semiconductor devices, improvement of fine pattern formation capability and of the positioning (alignment) function to form a pattern at the desired position.

However, in the case where the photographic technology discussed above is used, the required formation of fine patterns of approximately one micron is approaching the limits of formation capability due to limitations on the wavelengths that can be used in exposure.

In addition, in order to form a pattern at the prescribed position, it is necessary to detect the position of the pattern already formed on the substrate with high accuracy. In general, when performing position detection, as shown in FIG. 1, the pattern on the substrate 1 (concave portion in the drawing) is covered by a photosensitive

material 2 such as photoresist, and, moreover, flatness cannot be expected at the surface of the photoresist. For this reason, refraction, etc. of the pattern detection light becomes uneven, and there have been many cases in which problems are caused in position detection accuracy.

The purpose of the present invention is to provide a revolutionary semiconductor manufacturing apparatus that is designed by focusing on the above points and that is able to bring about improvement of fine pattern formation capability and improvement of pattern position detection accuracy.

To achieve the aforementioned purpose, the present invention is configured to perform, via a liquid, detection of a pattern on a substrate on which a photoresist (photosensitive material) has been coated or exposure and formation of a pattern.

The present invention will be explained in detail below using embodiments.

First, the basic principle of the present invention will be explained. In general, the pattern resolution limit R of pattern projection optical systems used in pattern formation for semiconductor devices, etc. is indicated by the following equation.

$$R = 0.61 \; \lambda/n \times \sin \theta$$

Here,

λ: wavelength of light used in exposure

n: refractive index of the atmosphere in which the exposure optical system is installed

θ: characteristic value of the reduction lens

In order to highly integrate semiconductor devices, the pattern that forms the semiconductor device must be made more fine, and it is necessary to improve the pattern resolution limit R of the projection optical system.

Therefore, up to the present, efforts such as ① shortening the exposure wavelength and ② making the characteristic value $\sin \theta$ of the lens larger have been made. However, the respective amounts of these are already close to the limits due to physical limitations. In addition, pattern projection exposure up to this point has only been performed in air, and in the above equation, it was always $n = 1$. Therefore, in the present invention, a liquid in which n is larger than 1 is used, and an attempt is made to dramatically improve the pattern resolution limit R.

FIG. 2 is a drawing that shows an example of application to a conventional reduction projection type exposure apparatus.

A reduction projection exposure apparatus is an apparatus that forms a semiconductor device pattern on the entire surface of a substrate 1 while reducing an original image pattern 5 via a reduction lens 4 each time a substrate 1 on which a photosensitive material (photoresist) 2 has been coated is moved by a predetermined amount and performing projection exposure onto the substrate 1. In addition, in the present apparatus, the photosensitive material 2 that is coated onto the substrate 1 is held in a liquid 3. In this case, the liquid 3 is filled into the space between the substrate 1 and the reduction lens 4, and the photosensitive material surface that has been coated onto the substrate is kept in the liquid. Then, the liquid 3 is filled so that a portion of or all of the reduction lens 3 [sic; 4] is submerged as shown in the drawing. Furthermore, as shown in FIG. 3, the configuration may be such that a nozzle 9 is provided at a portion of the reduction lens 4, the liquid 3 is caused to flow in via a liquid inflow port 8 thereof and flows out onto the substrate 1 to keep the photosensitive material surface in the liquid.

Note that, in the drawing, 6 is an illumination system that exposes the pattern, and 7 is a pattern position detector.

In the relevant configuration, if the high-resolution reduction lens that can be obtained and used in this apparatus is, for example, $\lambda = 0.436$ microns and $\sin \theta = 0.28$, when the refractive index n of the atmosphere in which the exposure optical system is installed is changed to be larger than 1, improvement of the resolution limit R is possible as shown in FIG. 4.

That is, in contrast to the resolvable line width having been 0.95 microns when exposure was performed in air as has been the case up to the present, for example, by using a liquid in which $n = 1.36$ (for example, ethane trichloride trifluoride) or a liquid in which $n = 1.53$ (for example, chlorobenzene), it is possible to make the resolution limits more fine to 0.69 microns and 0.62 microns respectively, and it is possible to dramatically improve pattern formation capability.

In addition, if the refractive index n_P of the photoresist coated onto the substrate and the refractive index n_L of the liquid are made the same, as discussed above, correction is performed by the liquid as shown in FIG. 2 even if we assume that the photoresist surface is not flat, so it is possible to drastically reduce adverse effects resulting from photoresist which have occurred up until now during pattern detection, and stable, highly accurate pattern detection becomes possible.

Another effect of the present invention is that, since it is possible to maintain the level of cleanliness of the liquid used through techniques such as distillation, one can expect prevention of the occurrence of defects attributable to the fact that dust contained in the air adheres to the photoresist surface as has been the case up to the

present. In particular, for sub-micron fine pattern regions formed by reduction projection exposure apparatuses, it has been thought to be difficult to remove fine dust contained in the air, and the relevant benefits of the present invention are considered to be great.

In addition, with respect to positioning error resulting from expansion and contraction of the substrate accompanying temperature changes during the exposure operation, since it is possible to perform temperature control of the substrate using a liquid with a high thermal capacity in comparison with air, it has various advantages such as the ability to prevent substrate temperature changes in advance.

Note that in the embodiment above, the explanation was limited to a reduction projection type exposure apparatus, but the present invention is not limited to this, and its effects would be great even if it were applied to a magnification projection exposure apparatus that forms a fine pattern on a substrate or to apparatuses for inspection and measurement of fine patterns on a substrate.

Brief Explanation of the Drawings

FIG. 1 is a cross-sectional schematic drawing that shows an example of a substrate on which a pattern has been formed, FIG. 2 is a partial cross-sectional schematic drawing that shows an embodiment of the present invention, FIG. 3 is a partial cross-sectional schematic drawing that shows another embodiment of the present invention, and FIG. 4 is a diagram that shows an example of the effects of the present invention.

1	substrate
2	photosensitive material
3	liquid
4	reduction lens
5	original image pattern

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